

JOURNAL OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS

MARCH, 1930

Featuring

**Hydraulic and Mechanical
Features of Bellows Falls
Hydro-Electric Plant**



Vol. XVII

No. 3

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Published Monthly, except July and August, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, \$4.00 a Year (10 Copies)
50 Cents a Copy

Copyright, 1930, by the Boston Society of Civil Engineers.
Entered as second-class matter, January 15, 1914, at the Post Office
at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in
Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

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BOSTON
WRIGHT & POTTER PRINTING COMPANY
32 DERNE STREET

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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HYDRAULIC AND MECHANICAL FEATURES OF BELLOWS FALLS HYDRO-ELECTRIC PLANT OF THE NEW ENGLAND POWER SYSTEM

BY EDWIN A. DOW,* MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS

(Presented on February 19, 1930, at a joint meeting of the Boston Society of Civil Engineers; Northeastern University Section, Boston Society of Civil Engineers; Massachusetts Institute of Technology Student Chapter, American Society of Civil Engineers; Tufts College Student Chapter, American Society of Civil Engineers; and the Harvard Engineering Society)

BELLOWS FALLS, MASSACHUSETTS, on the Connecticut River, has been a scene of hydraulic activity since very early days. In 1792, while Washington was President, work was begun on a timber dam and a canal 22 feet wide and 4 feet deep by "a Company for Rendering the Connecticut River Navigable by Bellows Falls." This work was financed by money from London, and was completed in 1802. The canal accommodated a traffic of log rafts and flat-bottomed boats with square sails, — handling rum, lumber and sundries. The navigation project was disappointing, however, as the river traffic never attained much volume. Only once, in 1831, did a steamboat get as far up the river as Bellows Falls, and in 1849 the opening up of the railroads destroyed the canal's usefulness except for power purposes. Water was taken from the canal for power as early as 1829, however, and was taken increasingly as time went on. Between 1875 and 1883 important improvements were made, including the construction of a new dam, the enlargement of the canal to a section 75 feet wide and 17 feet deep, and the installation of new headgates. In 1900 the dam was rebuilt with concrete, completing the old canal company's system, which was patterned after those at Lowell, Lawrence and Holyoke. Water was sold on long-time leases to mills which used it through their own water wheels, as they saw fit. The total capacity was approximately 10,000 horsepower, developed in some seventy individual turbines.

* Designing Engineer, New England Power Construction Company, Boston, Mass.

The problem of redeveloping the Bellows Falls site to eliminate the obsolete and relatively inefficient hydraulic system and replace it with an up-to-date plant of a type consistent with modern utility requirements involved increasing the capacity to the maximum possible, and providing pondage to permit operation for peak load demands. From

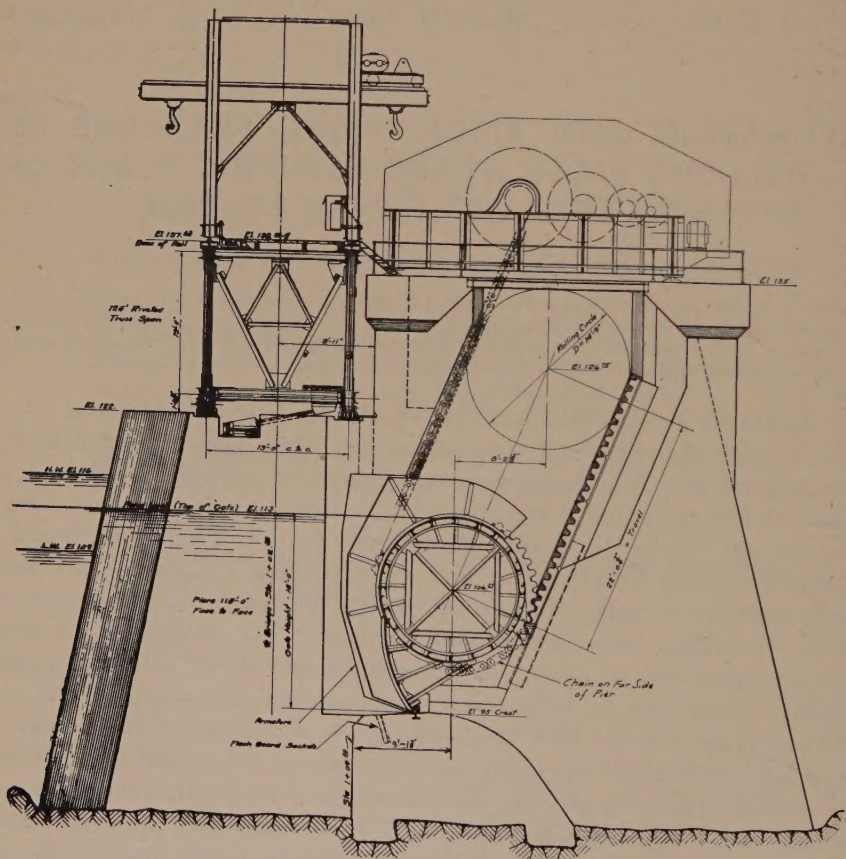


FIG. 1. — TYPICAL ROLLER GATE SECTION OF SPILLWAY
Crest at elevation 95. Two bays of 115 feet clear length each

the standpoint of capacity, the canal was found to be the neck of the bottle for the new plant. It was so restricted by property not economically obtainable that it could be widened and deepened to only a very limited extent. Its carrying capacity, however, could be greatly increased by raising the pond and operating with the water surface at a higher elevation, which would also provide additional head and pondage. Hence,

in spite of railroad and highway damages, and the necessity of purchasing additional flowage, it was found advisable to raise the operating pond level from elevation 102 to elevation 113 (Bellows Falls Canal Company datum). The new plant develops 60,000 horse power at 60-foot head, using three turbines with a combined discharge of 10,000 second-feet.

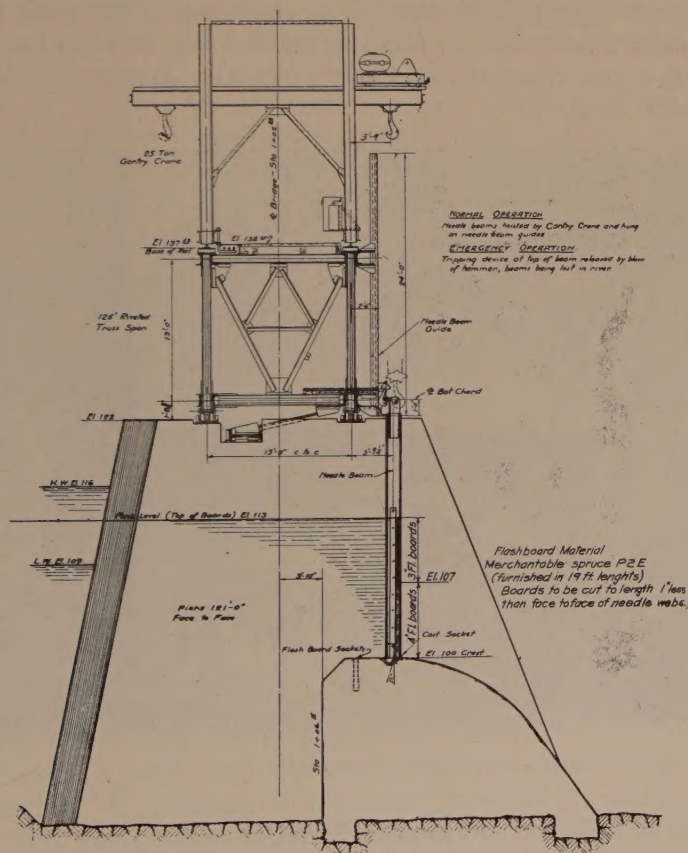


FIG. 2. — TYPICAL FLASHBOARD SECTION OF SPILLWAY

Crest at elevation 100. Two bays each 121 feet long and one bay 100 feet long

SPILLWAY

In the design of the spillway there were two fundamental requirements: first, under normal operating conditions the water surface had to be carried 11 feet higher than previously; and second, under flood conditions the discharge at any given stage had to equal or exceed that of the old spillway in order to avoid flood damage chargeable to the new

development. The old dam had fixed crests at elevations 100 and 102, and was very irregular in plan, since it followed the high points of the ledge across the river. The new dam crosses the river in a straight line and has fixed crests at elevations 95 and 100. In order to obtain maximum reliability in operation two different types of crest control were adopted: stanchion flashboards on the crests at elevation 100, of which there are two bays 121 feet long and one bay 100 feet long; and roller gates on the crests at elevation 95, of which there are two bays of 115 feet clear length each.



FIG. 3. — ROLLER GATE — UPSTREAM VIEW

ROLLER GATES

The roller gates are of the M. A. N. (Maschinenfabrik Augsburg-Nürnberg) type, and are made up of steel cylinders $13\frac{1}{2}$ feet in diameter and 121 feet long over all. To the cylinders are attached steel aprons provided with oak sealing strips, which, when the gates are closed, bear on steel sills at elevation 95, so that the entire height of the gates becomes 18 feet. Tightness at the ends is obtained by oak seals bearing upon hollow plate steel faces set in the concrete piers. Each gate is operated by means of a motor-driven hoist of 385,000 pounds' capacity, which rolls the gate up an inclined rack by a chain connection at

one end. The rate of travel is $\frac{1}{2}$ foot per minute, and the clear waterway with the gate in its open position is 115 feet long by 25 feet high. The roller type gates were adopted primarily because of the size of unobstructed opening which they provide, and the consequent insurance against clogging by ice or any floating débris which may come down the river. The combined capacity of the turbines and the two gates at a pond level of 113 is about 70,000 second-feet. Floods of this magnitude are expected about once in three years.

The M. A. N. gate, while still relatively new in the United States, is one which has been used for a number of years in Europe under a wide range of conditions, including the severe winter temperatures encountered in Norway. It is easily kept free from ice by a moderate amount of heat properly applied. At Bellows Falls freezing at the end seals is prevented by space heaters used in the cellular steel facings of the piers. Each gate requires about 8 kilowatts for this purpose. No serious tendency for the gate to freeze along the bottom seal has been experienced, but it is customary to open each gate a few inches once a week in order to make sure that it will be in condition to operate when required.

FLASHBOARDS

The three bays with crests at elevation 100 are provided with stanchion type flashboards 13 feet high. The stanchions consist of 16-inch I-beams spaced 6 feet 3 inches, center to center, between which 4-inch planks are inserted. At the top the I-beams are attached to specially designed latches which slide up and down in guides mounted on a steel bridge spanning from pier to pier. This bridge extends the entire length of spillway and accommodates a 25-ton gantry crane which is used in the tripping and handling of the needles.

The design of the flashboard control affords considerable flexibility in operation. If it is desired to remove boards at the top in order to provide spillway between the needles these can be pulled up separately or in panels by the crane and stored until replacement is necessary. If an entire bay is to be cleared the normal procedure is to hook the needles at the top, one after another, with the special crane hook, pull them out of the sockets in the crest, and lift them clear of the water by sliding the latches up in the guides. The needles are left suspended in the raised position until it is time to replace them. When this procedure is followed those boards which have not already been removed are lost downstream. As a final alternative the crest can be cleared in an emergency by simply tripping the latches and releasing the beams at the top,

allowing them to be carried downstream with the boards. The emergency tripping operation can be performed by one man with a hammer, and affords a last resort in case all sources of power should fail, though this is a very unlikely contingency at Bellows Falls.

The combination of roller gates and stanchion flashboards provides a very flexible method of operation, and insures spillway capacity under all conditions. The roller gates afford an easy method of passing normal floods and regulating the pond level to any desired height, while the



FIG. 4. — FLASHBOARD CREST

Showing stanchions before boards were placed

stanchion type boards provide for emergency spillway capacity which can at all times be made available. Replacement of the boards is accomplished by drawing the pond through the turbines and roller gates after the flood has dropped to a discharge of about 20,000 second-feet.

An interesting phenomenon has been experienced in connection with the needle beams. The tongues at the bottom ends of these are beveled and fit into beveled sockets in the dam. These bevels were provided in order to reduce the crane lift necessary to disengage the needles, and dynamometer tests have shown that a pull of about 4,500 pounds is

required to lift a beam from the socket. In spite of this, however, the beams have repeatedly shown a tendency to rise of their own accord, so as to cause a serious leakage under the flashboards, although none of them has ever risen entirely out of its socket. A holding-down device has now been installed to prevent this, but no adequate explanation of the tendency has yet been suggested.

CANAL

The design of the canal presented an interesting problem, both on account of the desirability of carrying high velocities, and on account of the steep side slopes necessary, namely, 1 on $1\frac{1}{4}$. With velocities of 6 feet or more per second it was necessary to provide a lining of some kind. The type adopted consists of concrete ribs spaced 20 feet, center to center, along the slopes, topped out with a concrete head wall about 6 feet high. The bottom of the canal and the areas between the ribs are protected by a rock paving 18 inches deep. Most of the stone used was of fairly large size, much of it being "cut stone" salvaged from the old head works, so that a relatively smooth paved surface was obtained. A trench about 2 feet deep and 4 feet wide was excavated along the foot of the slope on each side. This was filled with selected heavy paving, and provides a substantial toe to develop such reaction as may be necessary to support the concrete ribs.

Recent observations of the canal indicate that the lining will prove very satisfactory. During the first months of operation, before the pond had been raised to normal height, velocities materially exceeding the expected were sometimes reached without injury to the paving, and while inspection by a diver has disclosed moderate settlement at a few points, which might be expected as the lining adjusted itself to a uniform bearing on the foundation, there has been no tendency to ravel.

POWER HOUSE LOCATION AND SUBSTRUCTURE

The location of the power house presented an interesting problem. Numerous studies were made covering sites ranging from a position just below the old branch canal intake to the river edge several hundred feet downstream. The upstream location involved heavy rock excavation for the tailrace, while the downstream location required expensive concrete forebay walls, or penstocks of considerable length. The studies indicated the upstream location to be more economical, and its selection was well justified by the actual construction costs. The layout at this location was originally made with the expectation of using a large tailrace tunnel, but further study developed the fact that the deep open cut



FIG. 5. — CANAL LINING
Showing concrete ribs and section of paving



FIG. 6. — COMPLETED CANAL IN OPERATION AT LOW STAGE

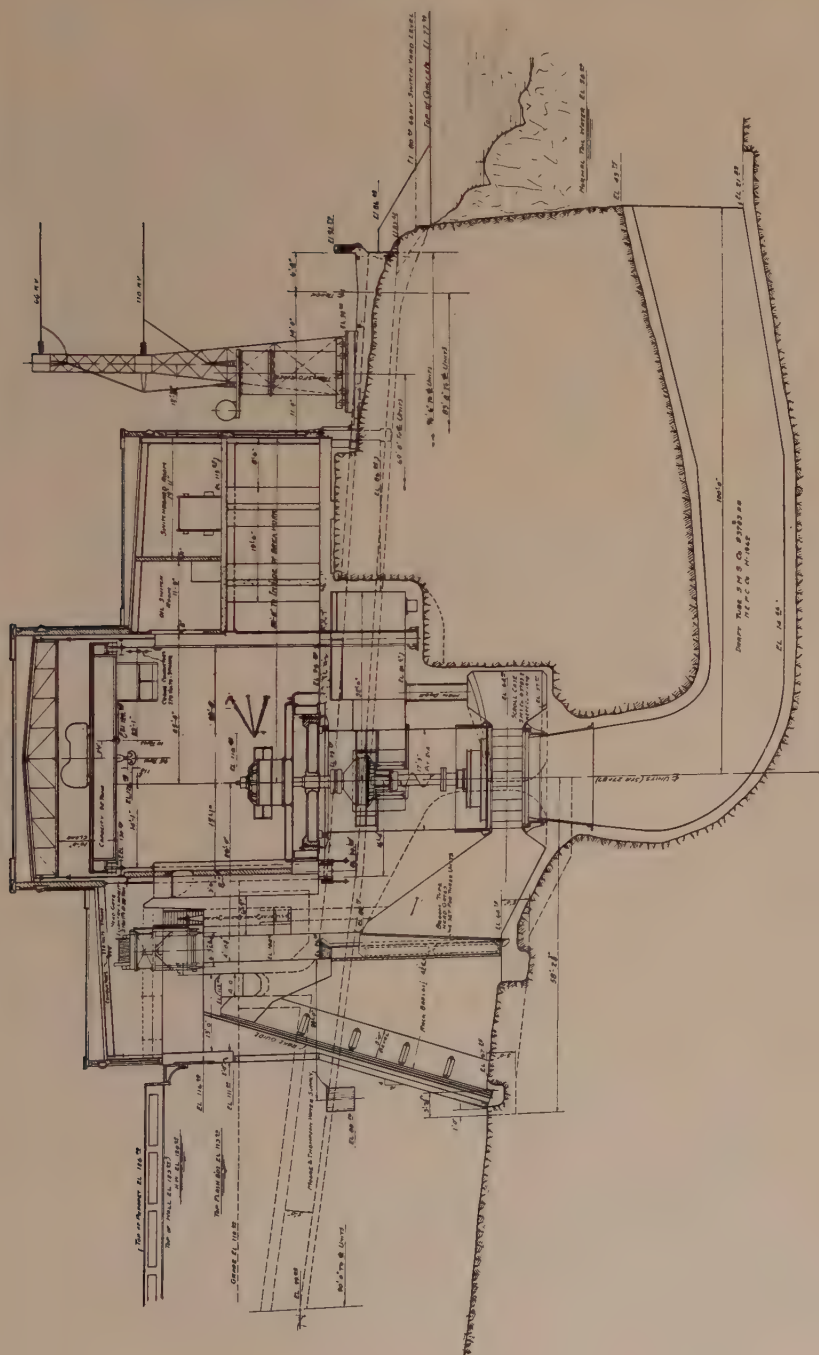


FIG. 7. — TYPICAL POWER HOUSE CROSS SECTION

design finally adopted would be more economical as well as much better from a hydraulic standpoint.

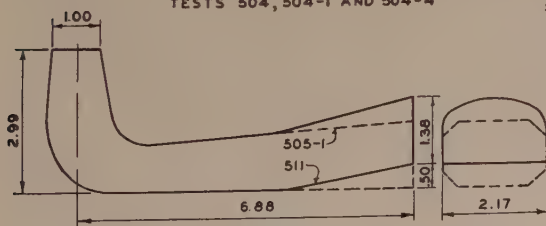
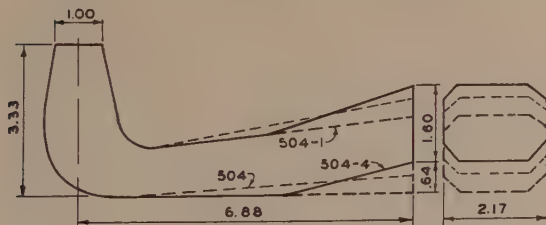
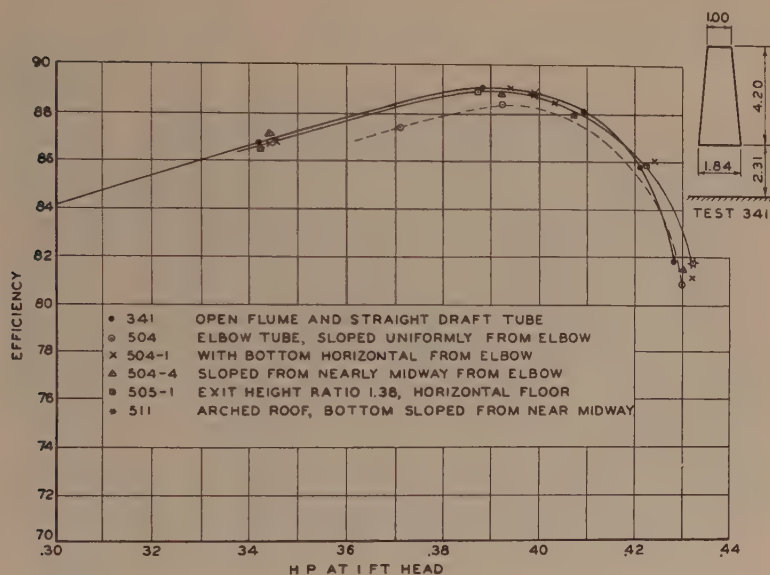
The ledge elevation at the power house site resulted in a very unusual substructure. The conventional type of design first considered provided for complete excavation of the ledge to the bottom of the draft tubes, and the construction of the concrete substructure from the bottom of this excavation up. As an alternative, a study was made based on excavating only enough ledge to accommodate the scroll cases, discharging the water through individual draft tube tunnels. This permitted the retention of a large mass of ledge over the draft tubes to provide stability against head-water pressure, instead of eliminating this natural dam and replacing it with an artificial one of concrete. This draft tube tunnel scheme was adopted, and it worked out in a very satisfactory manner.

DRAFT-TUBE DESIGN

Owing to the necessity of excavating ledge to accommodate the complete turbine settings, and due to the restricted area available, there was an unusual incentive to reduce the spacing of units to the absolute minimum. The necessity of preserving adequate ledge piers between draft tube tunnels, however, at first seemed to present a serious obstacle to any material reduction of this spacing, which, with normal draft-tube proportions, would have been determined by the draft-tube width. Therefore a program of model testing was carried out in the turbine manufacturer's laboratory, with very satisfactory results, and the unit spacing of 44 feet 9 inches finally adopted was fixed entirely by scroll case requirements, and was considerably less than normal, even from this standpoint.

The final draft-tube design was based on a tube of very narrow proportions, originally developed in connection with the replacement of the three-runner units at the Vernon plant with a single-runner turbine. This tube has a width of only 2.17 times its throat diameter, which resulted in piers between draft tubes 13 feet 9 inches thick. Some of this, however, is taken up by the concrete lining, and the actual thickness of ledge piers was only about 10 feet, which would have been impossible in some kinds of material, but presented no difficulty in the type of ledge encountered in this location.

In order to avoid excessive tailrace excavation it was desirable to carry the horizontal leg of the draft tube on a rising grade from the low point of the elbow to the outlet. The model tests showed this to be possible without loss in efficiency if the slope was confined to the downstream half of the leg.



EXPERIMENTS OF
S.MORGAN SMITH CO. AT YORK,
PA., 1927, FOR NEW ENGLAND
POWER COMPANY.
THROAT DIAMETER 16"
NOMINAL RUNNER DIAM. 12"
 $N_p = 122$

FIG. 8. — MODEL DRAFT TUBE TEST DATA



FIG. 9. — TAILRACE EXCAVATION SHOWING DRAFT TUBE TUNNELS

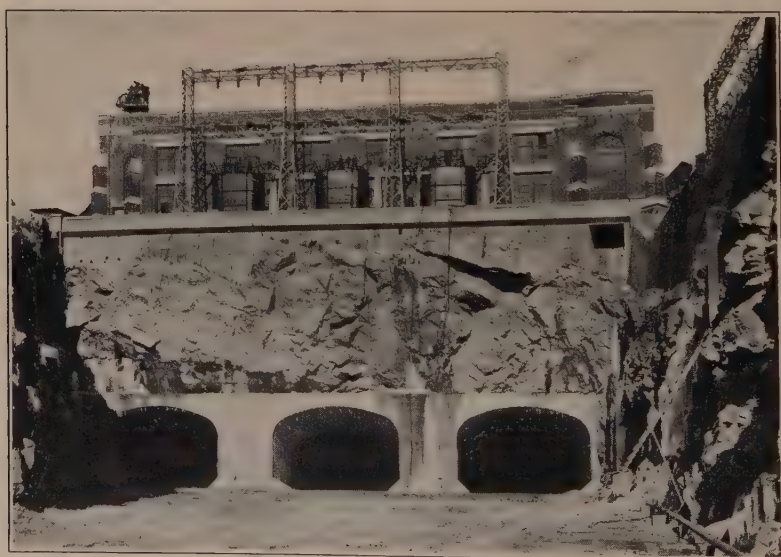


FIG. 10. — VIEW FROM TAILRACE SHOWING COMPLETED DRAFT TUBES

In addition to being very narrow the draft tubes are also of unusual length. This length was a matter of some concern when the studies were made, because of the uncertainty as to its possible effect on regulation. It was thought that this condition might make hand phasing impossible, and provision was made in the plans for phasing automatically. Experience has shown this to be unnecessary, however, and while some difficulties were experienced in adapting the governor to all requirements, these have now been satisfactorily taken care of, and the situation with respect to regulation is entirely normal. The greatest difficulty was encountered in obtaining a governor adjustment which would hold the



FIG. 11. — DOWNSTREAM VIEW OF COMPLETED STATION

speed sufficiently constant under no load to permit easy phasing, and at the same time would leave the governor able to respond satisfactorily to demands for load changes, either by the switchboard operator or by the system speed fluctuation. The solution was finally found in the installation of a by-pass on the governor dash pot which would be closed to give a relatively slow movement of the wicket gates in the phasing range, and would be opened automatically to allow free movement under normal load-carrying conditions.

FREQUENCY CONTROL

An interesting feature in connection with the regulation problem is the fact that automatic frequency control apparatus has been installed at Bellows Falls, this being the second plant of the New England Power

System so equipped. By means of this control it is possible, taking load fluctuations on this plant alone, to hold the frequency within $\frac{1}{20}$ of a cycle of normal (corresponding to a speed variation of about $\frac{1}{12}$ of 1 per cent), not only on the New England Power System, but on interconnected systems extending into half a dozen states. Such regulation is expensive, however, since it results in operating through the

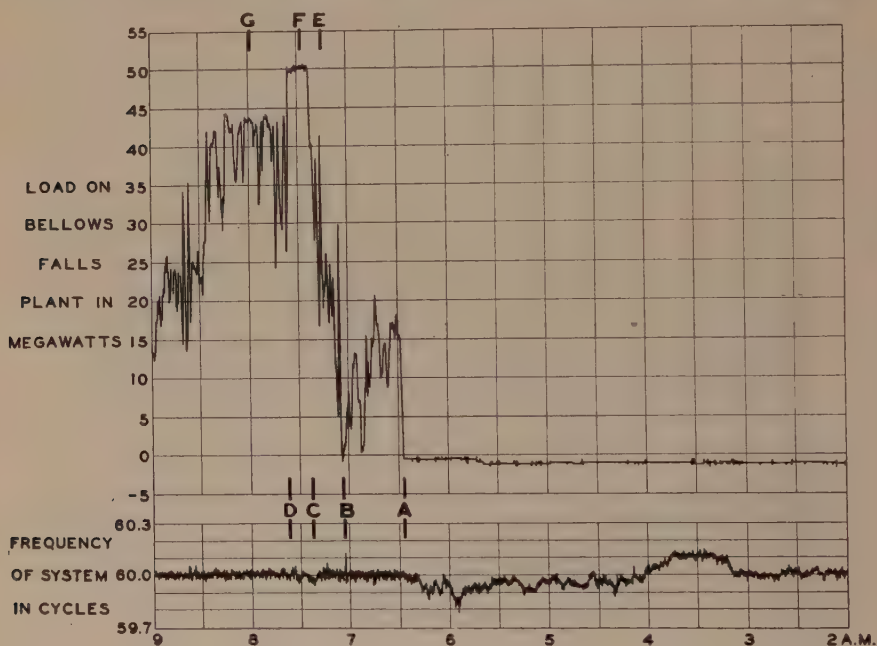


FIG. 12. — REGULATION CHART

2 A.M. to point A, non-automatic regulation, Bellows Falls motoring

A to C, automatic regulation by Bellows Falls, except for instant at point B, when load dropped, causing return to motoring

Anticipating load increase, additional plant, thrown on system at E, fails to pick up load with sufficient rapidity, so that from C to D Bellows Falls plant is wide open and cannot maintain speed

D to end of chart, typical automatic regulation entirely by Bellows Falls plant

complete gate range and causes a serious reduction in the average efficiency. When more plants are equipped with automatic control apparatus this condition will be improved, since the departure from the most efficient load will be reduced as more units share the fluctuation.

GENERATING UNITS

The three units at Bellows Falls are of fairly standard construction, the turbines being rated at 20,000 horse power each at 60 feet head, and the generator rating is 17,000 k.v.a. The speed is 85.7 revolutions per minute. The turbines have no unusual features, with the exception of the speed rings, which are of column-bolt construction instead of being built with solid cast vanes, which is now more common. The two types were carefully checked by tests on the model, but in the Bellows Falls setting no difference in performance could be detected. The column-

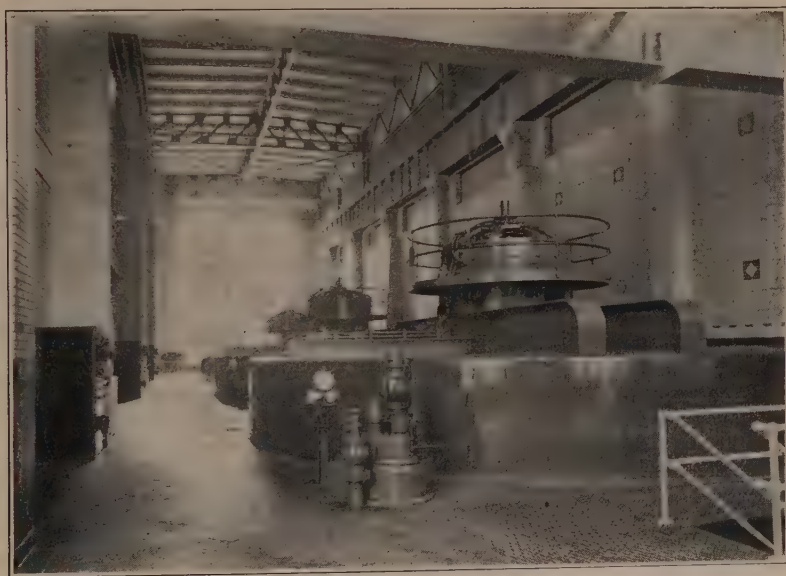


FIG. 13. — GENERATOR ROOM

bolt construction resulted in a smaller outside diameter of speed ring, which permitted a corresponding reduction in over-all dimensions of scroll case, and favored the close spacing of units which was desired. The turbines are provided with adjustable lignum vitæ steady bearings. Each unit is provided with two 3-inch air valves to admit air through the top plate and break the draft-tube vacuum when the unit is motoring.

The thrust bearings are of the Gibbs type, of 550,000 pounds' capacity, 63 inches in diameter, and are supported below the generators on 60-inch plate girders spanning the turbine pits. A babbitted steady bearing is located immediately below the thrust bearing, and the cus-

tomary lower generator steady bearing is omitted. The generators, however, have steady bearings above the rotors, as usual. When there is sufficient head room to permit its use this arrangement of bearings is ideal both from a construction and an operating standpoint. The thrust bearing and its support, being supplied with the turbine, can be completely erected and lined up with the latter by the turbine erector, who turns the hydraulic unit over to the generator erector with the turbine shaft to line and grade, so that the questions of responsibility which frequently cause friction during erection are eliminated. The generator rotor can be removed for repairs, etc., without disturbing the thrust bearing or the alignment of the turbine shaft, which considerably reduces the time necessary for dismantling and reassembling. Since it is found that the generators require overhauling much more frequently than the turbines, the accessibility of the rotor is very advantageous.

The governors are of the actuator type, with motor-driven heads, the actuators being located on the generator floor, while the pumps, tanks, piping, etc., are located in the basement. The flyball motors take current from transformers tied into the generator leads.

The generator stator frame is of plate steel welded construction, and the rotor has a laminated plate steel rim built up on a cast steel spider. Each generator has a direct-connected exciter. The generator WR^2 is 14,000,000, and the unit inertia is about 5,300,000.

Air for generator ventilation is drawn in through the windows and passes down through gratings into the basement, whence it is drawn into the wheel pits and discharged by the generator fans into envelopes enclosing the machines. These envelopes discharge into vertical shafts which convey the warm air to the intake house, where it helps materially to prevent ice troubles in the winter. Provision is made by a suitable system of dampers for any desired amount of recirculation to keep the station at a comfortable temperature at all seasons. This system of ventilation results in low pressures in the power house, and is sometimes objectionable because of the consequent leakage of cold air about windows and doors. At Bellows Falls, however, no annoyance has been experienced from this source, since the switchboard room is segregated from the generator room and is served by a steam heating installation.

INTAKE

The turbines are protected from dangerous trash by racks of conventional type composed of round edged flats $\frac{1}{2}$ inch thick by 6 inches wide, spaced $4\frac{1}{2}$ inches, center to center. The racks are supported by built-up girders designed to present the minimum obstruction at the

points of contact. The proportions are such that with water at elevation 116, and racks bulkheaded or clogged with ice, the stress in the bars and in the supports will be, respectively, 25,000 pounds and 20,000 pounds per square inch.

In spite of the fact that two ice booms are provided, one at the upstream end of the canal and one just above the power house intake,

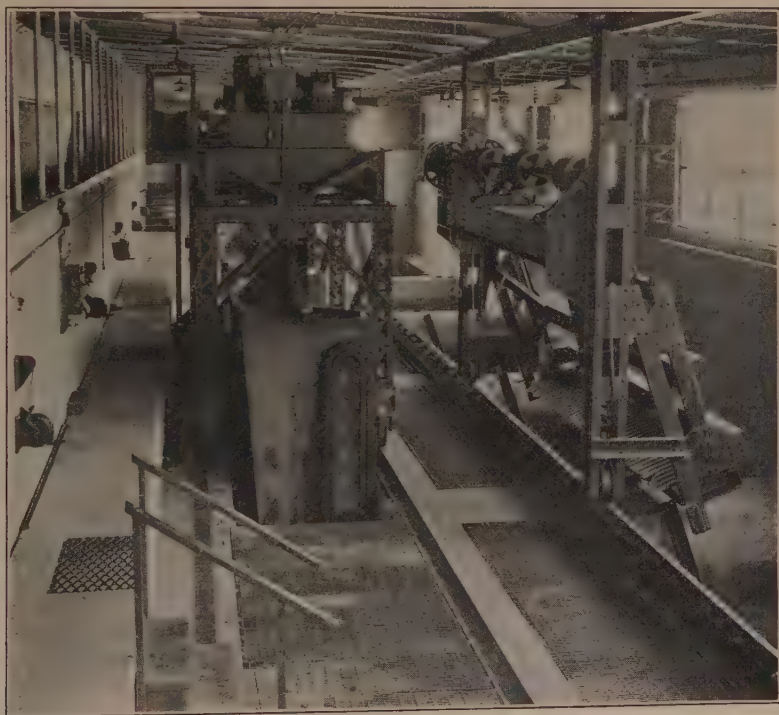


FIG. 14. — INTERIOR VIEW OF INTAKE

Showing Broome gates and rack rake

much uncertainty was felt when the plant was designed regarding the amount of trouble to be expected from ice. Experience to date indicates that the booms will afford satisfactory protection against river ice, but the thin sheet which forms on the canal during a week-end shutdown in cold weather is sufficient to give the operators considerable work for several hours when load is picked up. In order to take care of ice and trash, a concrete-lined trash sluice 8 feet high by 5 feet wide was constructed past the east end of the power house. This is provided at its

upper end with a steel gate 12 feet wide by 10 feet high, arranged to open by lowering, so that any desired amount of water can be spilled over it. Most of the canal ice is deflected through this sluice by the diagonal boom immediately above the intake.

To care for ice and débris which reach the racks a traveling rack rake is provided, as well as a compressed air cleaning installation. The latter, designed along the lines of the installation originally worked up and tried out at the Alabama Power Company's Mitchell Dam Plant, consists of a compressor, a large air tank, and a system of pipes terminating in horizontal runs immediately downstream from the toe of the racks. These horizontal runs are 2-inch pipes perforated with $\frac{3}{16}$ -inch



FIG. 15. — COMPLETED INTAKE IN OPERATION AT LOW STAGE

holes spaced on $4\frac{1}{2}$ -inch centers staggered with the rack bars. All underwater piping is brass. When it is desired to make use of the air cleaner in the intake, the air tank, which has a volume of 96 cubic feet, is brought up to 125 pounds' pressure, the load is reduced on the unit to reduce the velocity through the rack to be cleaned, and the entire volume of air in the tank is discharged at the foot of the individual rack by means of a quick-acting valve. A rush of air and water rises along the face of the rack, bringing with it any débris which may be present. This action is so violent that at times trash as large as a railroad tie has been thrown several feet above the water surface. Trash which has been brought to the surface by the air cleaner is very easily hauled up by the mechanical rake and dumped into the sluice trough just downstream from the racks, whence it is conveyed by water admitted through a sluice gate at the west end of the intake to the trash by-pass and thence into the

tailrace. The combination of air cleaner and mechanical rake has proved extremely effective, and takes care of ice and trash in a most satisfactory manner, even under the severe conditions at Bellows Falls.

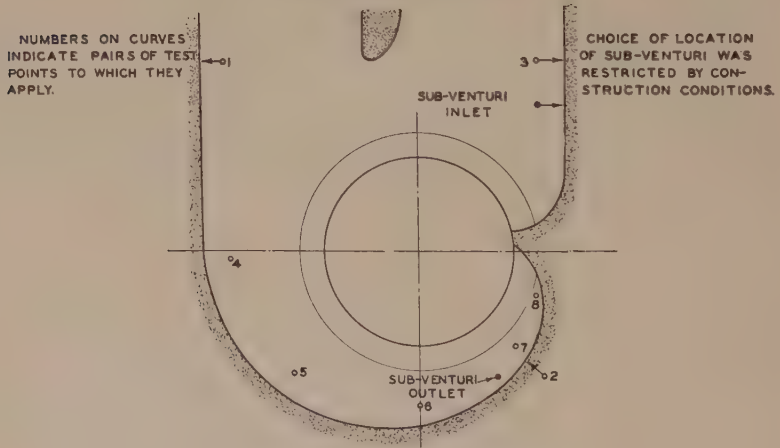
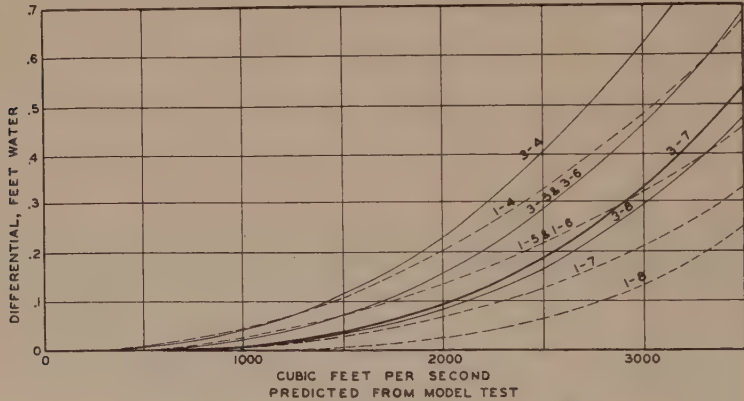
In order to permit draining of the scroll cases for inspection and repairs, two Broome gates, suspended from a traveling hoist, are provided. These can be used to close off the double openings leading to any one of the scroll cases. Since the probability of having to unwater more than one unit at a time in a plant of this character is negligible, it was not thought necessary to provide gates for all openings. The gates are 17 feet 4 $\frac{1}{2}$ inches wide by 24 feet high, and are each operated by means of a 50-ton hoist. In order to provide an ample factor of safety to absolutely insure closure, the bevel of the gate seats was increased beyond that customarily used in the Broome design. This would have called for excessive hoist capacity to permit opening the gates under full head, but the use of filler gates eliminated the necessity of providing for this condition.

SALT VELOCITY TEST

Upon the completion of the plant an efficiency test was made to check the performance of the units and determine their hydraulic characteristics as a guide in operation. The water measurements for this test were made by Prof. Charles M. Allen by means of the salt velocity method, using a stretch of the canal about 450 feet long. While some work had been done before by this method in moderate-sized open waterways, this was by far the most ambitious attempt to date at a canal test. The installation of pop-valves and electrodes was very carefully worked out, about 38 pop-valves, fed through 6-inch and 4-inch pipes, being installed. The use of an open water section required careful observations of water elevations at frequent intervals at several points along the canal to determine the instantaneous volumes necessary. This was in addition to the graphic determination of time and conductivity normally required, but the results obtained were, nevertheless, quite satisfactory. The test indicated a maximum turbine efficiency of about 93.5 per cent, which was gratifyingly high but not unexpected, since the customary step-up correction for increased size, when applied to the model test results, gave a value of over 94 per cent at the peak.

WATER METERING EQUIPMENT

The salt velocity test permitted the calibration of so-called "sub-venturis" which had been installed in the scroll cases, so that with suitable instruments a continuous record of discharge may be obtained.



BELLOWS FALLS SUB-VENTURI

FIG. 16. — PRESSURES IN MODEL SCROLL

The "sub-venturi," which had previously been tried out successfully at the Sherman Plant on the Deerfield River, consists of a pipe shunt connecting a region of high with a region of low pressure in the scroll case. The pressure differential creates a discharge through the pipe which is measured by means of a standard venturi meter inserted in the

line. The flow through this meter varies with the turbine discharge, and it is only necessary to determine the ratio of the shunt flow to the main discharge in order to have a record of the latter. In the case of the Bellows Falls scroll, observations made on the model indicated the pressure conditions to be expected at various points in the water passage, and it was a simple matter to determine the best location of "sub-venturi" inlet and outlet, and predict the approximate pressure differential which would be available to create a flow through the line. The differential actually measured in the field was slightly greater than that indicated by the model, and the differential produced by the discharge through the "sub-venturi" is ample to operate any one of several available venturi instruments.

EQUIPMENT FOR BELLOWS FALLS PLANT

Equipment.	Manufacturer.	Description.
1. Flood gates . . .	S. Morgan Smith Company	2 M. A. N. roller type. Height, 18', clear length, 115'. Hoist capacity, 385,000 pounds.
2. Stanchion flashboards	- -	Height, 13'. Horizontal boards, 4" thick, supported by 16" beams, 23' 6" long, spaced 6' 3", center to center.
3. Gantry crane . . .	Milwaukee Electric Crane Company.	25-ton capacity. Motor-driven hoist, trolley and bridge.
4. Ice booms . . .	- -	At canal inlet, 5 sections 100' long, 1 section 50' long. Width, 13' 6", keel depth, 5'. At power house intake, 3 sections 50' long. Same cross section.
5. Trash sluice gate . .	S. Morgan Smith Company	10' high by 12' wide. 2 screw stem hoists salvaged from old intake and motorized.
6. Mechanical rake . .	Newport News Shipbuilding and Dry Dock Company.	Width, 19'. Traveling type.
7. Head gates . . .	Philips & Davies, Inc.	2 Broome type gates, 17' 4½" wide, 24' high. Hoists, capacity 50 tons each, mounted on single motor-driven traveler.

Equipment.	Manufacturer.	Description.
8. Filler gates . . .	Coffin Valve Company .	18" by 24".
9. Power House crane .	Niles Crane Corporation .	Capacity 95 tons with 10 ton auxiliary hook. Completely motor driven.
10. Generators . . .	General Electric Company	3 units, 17,000 k.v.a., 6,600 volts. Direct connected exciters. Single steady bearing above rotor. Stator, plate steel. Rotor, plate steel rim with cast steel spider. WR^2 14,000,000.
11. Turbines . . .	S. Morgan Smith Company	3 units, vertical Francis type, 20,000 h.p. at 60' head, 85.7 r.p.m. Specific speed, full gate, 75.
12. Governors . . .	S. Morgan Smith Company	Actuator type, 115,000 foot-pounds' capacity.
13. Thrust bearings .	S. Morgan Smith Company	Gibbs type, 550,000 pounds' capacity, supported on 60" box girders at basement floor level.
14. Air compressor .	Sullivan Machine Company.	176 c.f.m. For station service and rack cleaner.
15. Air compressor .	Lipman Company . . .	15 c.f.m. For governor pressure tanks and air brakes.
16. Pumps . . .	Allis Chalmers Manufacturing Company.	350 g.p.m. Centrifugal, for transformer and bearing cooling water.

Discussion

PROF. H. K. BARROWS:* The power development at Bellows Falls is interesting as one of the earliest in New England. Before the reconstruction which Mr. Dow has described it was an inadequate and inefficient development with but only a part of the available power in use.

The new development is a little less in degree of development than the Turners Falls plant of the Turners Falls Power Company, downstream some 40 miles. Following are details of the extent of development of some of the plants on the Connecticut River:

* Professor of Hydraulic Engineering, Massachusetts Institute of Technology; and Consulting Engineer, Boston.

Connecticut River Power Developments

PLANT.	Drainage Area (Square Miles).	WHEEL CAPACITY.		
		Second-feet.	Second-feet per Square Mile.	Per Cent of Time Flow Available.
Turners Falls	7,100	12,000	1.70	35
Vernon	6,300	15,500	2.46	21
Bellows Falls	5,300	11,000	1.75	29
McIndoes Falls †	2,200	5,000	2.27	20 ±
Fifteen Mile Falls (lower development) †	1,650	12,000	7.60	2 ±

† Not completed.

As will be noted, these plants have capacities varying from the 20 per cent to the 35 per cent flow, with the exception of the Fifteen Mile Falls development, which will use a high rate of flow and be used as a peak or day load plant.

Typical Features of Bellows Falls Plant

Canal. — The absence of head gates at the entrance to the canal at Bellows Falls is an unusual feature.

Velocities. — Velocities at various points in passage through the wheel at full gate, as compared with usual practice, are as follows:

POINT.	Velocity (Feet per Second).	$\frac{V}{\sqrt{2gh}}$	Usual $\frac{V}{\sqrt{2gh}}$
Gates	3.32	0.055	0.07
Racks	$\left\{ \begin{array}{l} 1.84 \text{ gross} \\ 2.34 \text{ net} \end{array} \right\}$	—	—
Entrance scroll	7.5	0.12	0.12
Runner discharge	18.2	0.30	0.30
Exit draft tube	5.25	0.087	0.07

These all accord fairly closely with usual practice.

Power House. — Floor area is about 0.16 square feet per horse power of capacity, where many plants are double this amount. Davis bridge plant (60,000 horse power under 360-foot head) has 0.11 square feet per horse power.

Volume is about 6.2 cubic feet per horse power, which is also low. Davis bridge plant has 5.1 cubic feet per horse power.

These results reflect the compact nature of the design of the Bellows Falls power house.

Turbines. — The agreement between the results of model tests and field tests is especially good. The use of the salt velocity method in a large canal is novel and indicates a wider field of use for this method.

The draft-tube model tests and results obtained confirm the value of such tests in assisting in the suitable design of the structure.

This paper is of unusual interest and a valuable contribution in this field of engineering.

QUESTION: I should like to inquire as to the dimensions of the canal, also as to the amount of water it carried, and the maximum velocity. I didn't understand whether the bottom of the canal was lined or whether it was of rock; and I should like to know whether there was any appreciable scour of the bottom.

MR. DOW: The canal is 100 feet wide at the top, 36 feet wide at the bottom and about 29 feet deep. The bottom is lined, but not so smoothly as the sides. The bottom lining is more in the nature of riprap. It was, however, pretty well compacted by traffic through the canal during construction, — trucks, cranes, etc. While inspection by diver shows more irregularity in the bottom than along the slopes, I don't think that we would call it "scour." A good deal of the canal lining was placed in the winter, and possibly some of the lining in the bottom was not placed on the best possible material — in fact, I suspect that some of it was placed on ice. I recall a settlement of 18 inches in one place. We call the normal discharge 10,000 second-feet, but at full gate the turbines will take almost 12,000 second-feet, and the velocity runs somewhat higher than 6 feet per second.

QUESTION: I should like to ask about the compressed air cleaner. Does it dislodge the material that clings to the rack?

MR. DOW: I am not sure that I can answer the last part of that question definitely, but I know that the operators are well pleased with the air cleaner; in fact, I think they use it more than they do the mechanical rake.

To explain the action, the air is ejected suddenly from the small holes in the header across the bottom of the racks. It starts at a pressure of 125 pounds, and the pressure in the system decreases as the air in the tank is exhausted. I don't think the cleaning depends on the velocity of the air jet. As the air emerges from the pipes it comes out under fairly high pressure, and as soon as it emerges it starts to expand

and the bubbles start to rush to the top and obtain considerable velocity in doing so, so that there is a vigorous current of water as well as of air. If the load on the unit is adjusted so that this rush of water and air combined follows the slope of the rack, it brings nearly everything on the racks with it. The fact that a railroad tie has been not only thrown above the surface but far enough above to strike the roof of the intake house is good evidence of the violence of the agitation.

QUESTION: Do the roller gates operate by means of a hoist at both ends, or only at one?

MR. DOW: At one end only. The cylindrical shape of the gate, which provides great torsional stiffness, makes it unnecessary to operate from both ends; in fact, I think there would be a great deal of difficulty in applying hoists at each end of the gate, so that the two hoists would divide the load. It is rather interesting to note that there is a slight torsional deflection or change in shape of the gate as it starts to open, so that the instant the hoist takes the load and starts to lift the gate from the seat the water comes through at the end near the hoist first, and shoots along the length of sill in what seems a fraction of a second. There is a very decided tendency to discharge at the hoist end first.

QUESTION: How much clearance was allowed below the crane girder running along the power house above the top of the generator?

MR. DOW: I can't answer that in feet, but it is our practice not to allow any large margin in that dimension. We ordinarily work within 6 inches of actual clearances.

QUESTION: Does the proper operation of the air cleaner depend on having just the right velocity of flow through the intake, and also does the slope of the rack have to be reduced from the vertical and adjusted to the velocity of flow through the intake?

MR. DOW: I would not expect the operation to be extremely sensitive to that particular thing. I think the agitation of the water extends through a fairly wide range, and while there probably is some velocity at which the results are best, I don't believe it is necessary to split hairs in that respect.

QUESTION: Would Mr. Dow discuss the load conditions on that station? As far as I could judge from the load chart shown, the station is practically operated at no load, or a load approximating full load, so that the average for the day would be of little value. I would like to ask whether the station is usually operated at a very high percentage of full load or practically not at all.

MR. DOW: The chart shown was merely a sample covering a few

minutes, and indicated conditions which obtained during the time when this station was taking the entire load fluctuation from the New England Power System. While the station is operating as an automatic regulator I think that sample is likely to be typical. While the station is operating merely as one of the numerous stations on the system I really don't know what the load factor would be. Possibly Mr. Bell can tell us.

MR. W. R. BELL: * I think the load factor is about 50 per cent for the year. It is customary to concentrate the water available into the day period. If the river flow is such that it cannot all be conveniently put into days, then it will be used in the evening, after midnight, and week-ends in order of its value as compared with steam generated power. If water is low, and during the time of year when there are heavy peaks, the available flow is conserved for hours of peak load. It is merely a matter of putting the flow that is available into the time of day when it will be of most value.

MR. DOW: Except for this matter of automatic regulation, normal practice would be to operate at or near the point of maximum efficiency, would it not?

MR. BELL: It is our endeavor to use the water available at the most efficient point. There are, however, system conditions such as necessary stand-by capacity and capacity on the line for voltage or relay protection purposes which may make it advisable to put on, say, three machines when the water available could be used through two. In cases of this sort the load is split evenly between machines on the line in order to attain the highest efficiency possible in view of all controlling factors. An effort is made to schedule the plant load to bring the operation at as high a point on the efficiency curve as possible.

QUESTION: I would like to ask Mr. Dow what he means by automatic regulation?

MR. BRANDT: * Automatic regulation, or automatic frequency control, is intended to accomplish without the constant attention of the station operator, the maintenance of frequency within certain predetermined deviations from the normal. The apparatus at Bellows Falls might be said to take periodic snapshots of the frequency, and, according as it finds need for correction, closes the circuit to the governor synchronizing motor for a length of time proportional to the error which it has found. The automatic equipment is connected by relays in parallel with the ordinary governor motor control on the main switch-board.

* Of the New England Power System.

QUESTION: Have you had occasion to operate the roller gates under severe ice conditions in cold weather? If so, have you had any trouble?

MR. DOW: It is the practice to operate the gates through possibly 6 inches, that is, open them 6 inches, once a week during winter weather, in order to make sure that they are not frozen. There has not been occasion to open the gates wide while there was an ice cover on the pond, or anything of that kind. During last spring's run-off the gates passed the ice as it came down the river without doing damage, and they were opened after the ice had started to run. Last spring is the only experience we have had in handling the ice with the gates, but the evidence is that they can take care of the condition satisfactorily.

OF GENERAL INTEREST

HOW SHALL THE WATER FRONT BE DEVELOPED?

Conflict between the Geranium Planters and the Old Salts in Port Development — Proper Design and Landscaping of Reclaimed Water Front Will Serve All Interests

*By Roy S. MacElwée**

In port and city planning there is all too frequently a bitter struggle between the geranium planters and the old salts. The geranium planters are landscape architects engaged in city and regional planning, looking upon bodies of water only as a feature in landscaping; while the water front interests look upon water only as a place to float a ship. Such conflicts have been long and bitter; for instance, at San Diego, California, where the derisive term "geranium planters" was picked up from the Director of the Port, Captain Brennan. As in nearly all controversies, the truth lies somewhere between. In spite of the fact that there is a tendency for the city planners to zone water-front activities as Class "2" industries, — that is, the most undesirable and obnoxious, dusty, noisy and odiferous group, — a careful analysis of port activities, together with the application of port development of city planning and landscaping principles, can result in unusually attractive and satisfactory solutions on the middle ground. There is nothing new in this

except its application in the United States. Few people realize that Paris is the greatest port in France, with an annual boat commerce along its quays of 15,000,000 metric tons. Rather attractive little cities with water front drives, such as Stettin and Kiel, have compromised the difference between parks and arterial highways and water front activities.

The first step is an analysis of the various functions of the integral parts or divisions of the planned and coordinated sea, river, lake or canal port. Without going into details, the metropolitan area of Boston involves all the possible combinations, — local, coast-wise and ocean shipping; parks and parkways; industries. The principal subdivisions are as follows:

1. Commercial terminals for ocean vessels — usually public utilities.
2. Industrial harbor for plants receiving and shipping quantities of materials — usually private enterprises.
3. Special activities, such as fisheries basins.
4. (a) Local traffic, usually of low spe-

*Of MacElwée & Crandall, Inc., Industrial and Civil Engineers, 134 Main Street, Cambridge, Mass.

cific value, such as sand and gravel, building materials, structural steel.

(b) Local passenger traffic, excursion boats, ferries, etc.

The commercial and civic value of æsthetics is slowly but surely gaining proper recognition. The press of motor traffic on city streets is demanding super-highways to reach the open country quickly and safely without the enormous cost of tearing down miles of buildings to widen streets. The city planner immediately looks at the low-lying foreshore, which is the only hope for the expansion of the maritime commerce of the city, and draws attractive plans for reclaiming this foreshore for parks and super-highways. In Vancouver, B. C., the plan has appropriated for parks the only available space for the expansion of the Port of Vancouver. Even the wharves for ocean-going commerce, if properly planned, treated architecturally, and developed as one would develop a modern monumental union railway station, need not in the least interfere with the parkway development. In fact, such passenger wharves should have attractive access and a landscaped setting, while, on the other hand, the coming and going of ships never cease to attract the interest of citizen and visitor to the city.

Let us consider, however, for a moment, the fourth group, — local traffic, both building materials and other local deliveries, and passenger traffic. In drawing the plans for the comprehensive future development of the Port of Toledo, Ohio, it was found that another street could be added along the Maumee River, in front of warehouses, existing or to be constructed new, retaining a fairly narrow open wharf between the roadway and the ships' berth, with the traveling Gantry platform above the street served by a crane over which package freight destined to the water-

houses for local consumption and distribution could pass easily and quickly without interfering with the traffic. Further down the river, where there are extensive marshes and shoal water, it is possible to widen the highway to a total width of 185 feet, beginning 200 feet from the water's edge, leaving the upland reclaimed from the marshes for park and recreation purposes, with a possible stadium which requires vehicular access and parking areas. There is a place for rows of tennis courts, or even a small public golf course; also, under strict supervision and screened by means of tree planting and shrubs judiciously placed, the commercial and industrial activities by the riparian owners may be continued. This super-highway had the following units: tree and shrub strip, 20 feet; truck way, 30 feet; shrubs, 10 feet; speedway, 60 feet; shrubs, 10 feet; truck way, 30 feet; tree and shrub screen, 20 feet; sidewalk, 5 feet. Operated by electric locomotives, switching tracks are placed on both sides of the super-highway, but screened from view by the tree planting.

The local commerce of the port was served by a strip 200 feet between the super-highway unit and the river. Local packaged freight and passengers, excursion vessels, etc., were served by ornamental, although simple, transit sheds, in harmony with the pavilions of the park system. A well-proportioned but simple Italian Renaissance in concrete with red tiled roofs was suggested. These transit sheds were not continuous, but planted open spaces remain between any two sheds, at least twice the frontage of the shed, affording pleasant views of the river at frequent intervals.

The 200-foot unit, beginning with the water's edge, consisted of 30 feet of wharf apron with two tracks or channel rails laid flush, transit shed or open

storage or planting, 80 feet; a marginal dray way, 80 feet, carrying two tracks at shed side of the dray way, and two leader tracks, the channel rails flush with the pavement or with the grass planting. The remaining 7 feet was a sidewalk.

Building materials, such as sand, gravel, structural steel, brick, stone, etc., all essential to the present and future growth of the city, should be handled at such a riverside wharf in Toledo, just as in Paris. Areas reserved for building materials along the 200-foot wide strip need not be obnoxious or disfiguring, provided the areas remained under the control of the park commission as to their policing, and providing screened planting or trellises with vines, or walls to prevent the scattering of bulk materials, such as sand and gravel, are properly designed and located.

Where the riparian owners are industrialists, as the case for about two-thirds the length of the lake front improvement at Cleveland, it is necessary to plan to connect shipside with the plant, across the super-highway, by means of elevated conveyors of various designs, according to the nature of the product to be handled. This overhead conveyor would take the form of an architecturally treated concrete bridge, the pillars resting on the planted strips, and perhaps the coldness of the columns of the "triumphal archway" relieved with climbing ivy. Along the rivers and canals in Berlin, numerous industries are served by overhead carriers across a marginal driveway. However, aside from substantial and sometimes ornamental steelwork, no attempt has been made to mask the conveyors by the applica-

tion of the architectural triumphal arch, although this is done in many places in Berlin where the elevated railroad tracks cross parkways and water front drives. There is nothing new under the sun — only new application and use.

A reclamation of the present river front dump would give water transportation, vehicular traffic, and playground relief, each element conceding very little to the other, and all contributing to a more comfortable, more artistic, and more economical city.

In the above discussion it must be borne in mind that the problem is concerned with the congested business and intermediate area between the business center and the recreational and residential suburbs.

The same sort of solution in the reclamation of the foreshore of the city of Cleveland from the park system into the center of the city along what is now a straggly and partly submerged lake shore, is another instance where the combined use offers a logical solution for all of the elements, and with careful landscaping and planning may be just as attractive as the banks of the river Seine in Paris, where enthusiasts maintain that even the peat and sand piles are artistic.

It will be necessary to leave the question of industrial plants with waterside connection by barge or lighter, such as the very successful industrial harbors of old Hamburg and new Venice-Marghera, for some other time. The point to be emphasized is that a reclaimed water front can serve the people as a park, as an arterial highway, and as a shipping point if properly designed and landscaped.

B. S. C. E. Elects First Feminine Member

At the January meeting Miss Mary Olga Soroka was elected to membership in the Society. Civil engineering is a profession which few of the feminine sex have entered. Miss Soroka occupies the unique position of being the only woman who has graduated in civil engineering at the Massachusetts Institute of Technology, and the first woman to join the Boston Society of Civil Engineers.

Binding of Journals

The Society has made arrangements to bind Volume XVI of the JOURNAL (1929) for those members desiring to take advantage of this service. The cost is \$1. JOURNALS for binding should be sent to the Secretary, B. S. C. E., 715 Tremont Temple, Boston, *not later than April 1, 1930.*

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

FEBRUARY 12, 1930. — A regular meeting of the Boston Society of Civil Engineers was held today in Lorimer Hall, Tremont Temple, and was called to order by the President, Frank E. Winsor, at 7.15 P.M. This was the annual joint meeting with the following student engineering societies: Northeastern University Section, Boston Society of Civil Engineers; Harvard Engineering Society; and the Massachusetts Institute of Technology and the Tufts College Student Chapters, American Society of Civil Engineers.

There were about 325 present at the meeting, and 275 attended the buffet supper and smoker which preceded it. During the supper, music was provided by the Northeastern University band.

Mr. J. B. Babcock, Secretary, *pro tem*, announced that the following had been elected to membership by the Board of Government on February 19, 1930:

Grade of Member: Constantino Antonelli, Wm. F. Covil, Wm. F. Donovan, Joseph I. Lamb, Chester F. Langtry,* Harold A. Palmer, Chester A. Ring, Jr., David Wexler. *Grade of Associate:* Justin

J. Michelson. *Grade of Junior:* Lawrence S. Burke, Anthony Chibaro, Francis T. Dinnan, Maurice J. Dionne, Wm. H. Fitzgerald, Donald F. Libby, John H. Lowe, Peter C. Malkowski, Arthur R. Murphy, Richard D. Murphy, Edwin J. O'Connor, David Olken, Arthur W. Peterson, Horace A. Van Name.

The Secretary presented the Resolution concerning arbitration which the Board of Government had recommended to the Society for adoption. He also presented the report on the subject which had been made by a special committee of the Board. It was —

Voted, That the Society endorse the practice of using an Arbitration Clause in construction contracts for the settlement of all (or a stipulated part of) existing and future controversies arising out of the Contract, and recommends making such clause applicable under the Arbitration Law of the state where the work is to be performed, provided such a law exists.

(This vote of the Society authorizes the submission of this question by letter ballot to the membership for final action.)

The President announced this was the annual joint meeting of the Boston Society of Civil Engineers and the student civil engineering societies of Technology,

* Transferred from grade of Junior.

Tufts, Harvard and Northeastern. He extended an invitation to their members to attend any meetings of the Society.

The President then introduced Mr. Edwin A. Dow, Designing Engineer of the New England Power Construction Company, Boston, Mass., who gave an illustrated talk on "Hydraulic and Mechanical Features of the Bellows Falls Hydro-Electric Plant."

Following this address a discussion was held in which Prof. H. K. Barrows, Mr. Dow and other representatives of the New England Power Construction Company took part.

Meeting adjourned at 9.30 P.M.

J. B. BABCOCK, *Secretary pro tem.*

APPLICATIONS FOR MEMBERSHIP

[April 20, 1930]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

HEALY, JAMES JOSEPH, Charlestown, Mass. (Age 25, b. Charlestown, Mass.) Graduate of Boston College in 1922;

graduate of Northeastern Polytechnic Evening School in 1929. Employed by W. A. Murtfeldt & Co., contractor, from 1922-28; with Boston & Maine Railroad, engineering department, from April, 1928, to date. Refers to *F. T. Flynn, R. F. Macaulay, J. J. Rourke, F. C. Shepherd.*

KAPPLER, THEODORE WILLIAM, Wollaston, Mass. (Age 24, b. Wollaston, Mass.) Graduate of Northeastern University Polytechnic School in 1928. During the summer of 1923 employed by Bethlehem Shipbuilding Corporation at Fore River in structural erection crew; from November, 1926, to November, 1929, has been employed by the Metropolitan District Water Supply Commission; from November, 1929, to date, employed on valuation work by Jackson & Moreland. Refers to *W. J. Alcott, Jr., L. M. Gentleman, K. R. Kennison, F. E. Winsor.*

NEW MEMBERS

Member

WILLIAM F. COVIL, 41 Conwell Avenue, Somerville, Mass.

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WILLIAM H. FITZGERALD, 47 Union Park, Boston, Mass.

GEORGE L. GORBELL, 24 Porter Street, Everett, Mass.

JOHN H. LOWE, 10 Tolman Place, Lynn, Mass.

ARTHUR W. PETERSON, 10 Central Square, Brockton, Mass.

PHILIP P. WHITE, 366 Payson Road, Belmont, Mass.

DEATHS

GEORGE BOWERS . Feb. 28, 1930

CLEMENS HERSCHEL . March 1, 1930

HECTOR J. HUGHES . March 1, 1930

WILLIAM E. MCCLINTOCK March 2, 1930

BOSTON SOCIETY OF CIVIL ENGINEERS

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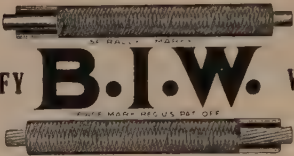
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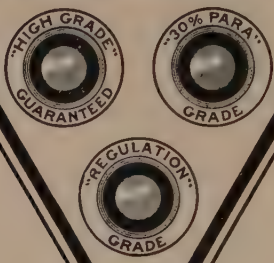
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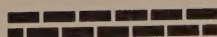
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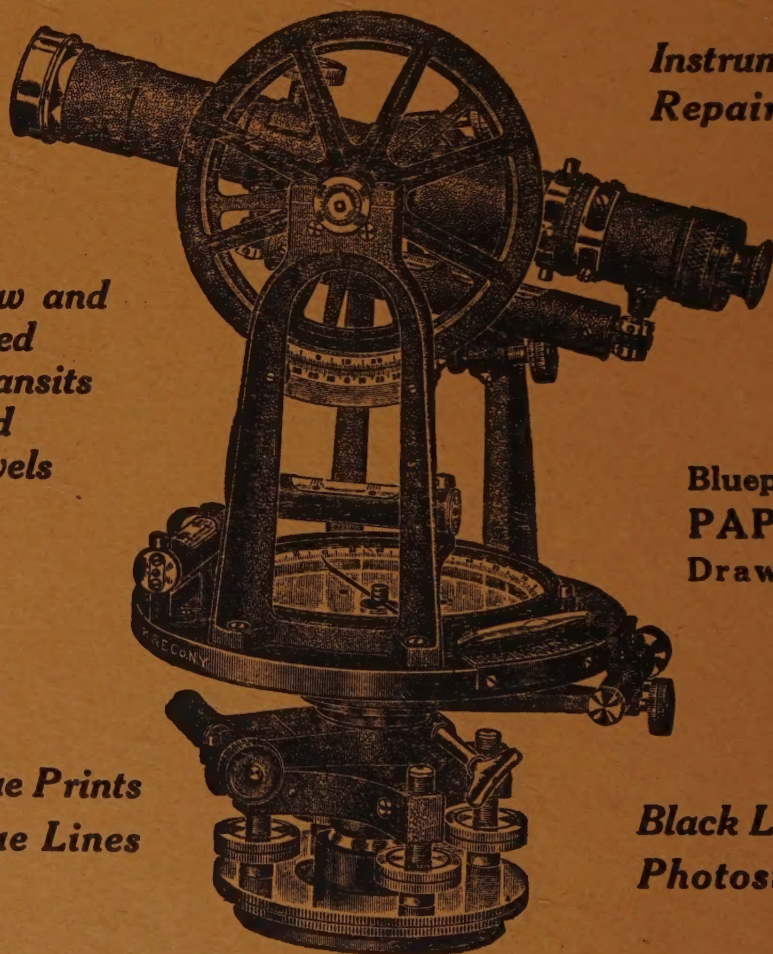
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